PATENT ABSTRACTS OF JAPAN

(2)

(11)Publication number : 2003-253390
(43)Date of publication of application : 10.09.2003

(51)Int.Cl. C22C 38/00
B21B 1/16
B21B 3/00
C21D 8/06
C21D 9/52
C22C 38/60

(21)Application number : 2002-061332
(22)Date of filing : 07.03.2002

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(54) WIRE ROD OF LOW-CARBON SULFUR-BASED FREE CUTTING STEEL, AND MANUFACTURING METHOD THEREFOR

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a wire rod of a low-carbon sulfur-based free cutting steel, having excellent machinability even when toxic Pb is not added thereto, and to provide a suitable manufacturing method therefor.
SOLUTION: The wire rod of the low-carbon sulfur-based free cutting steel comprises, by mass%, 0.02-0.15% C, 0.50-2.0% Mn, 0.05-0.20% P, 0.15-0.50% S, 0.01% or less Si, 0.01% or less Al, 0.002-0.02% N, 0.01-0.03% O, and the balance Fe with unavoidable impurities; and is drawn after hot rolling or hot forging, to have, when d (mm) is defined as a diameter of the steel wire, 2.8*logd or more of an average width (μm) of sulfide-based inclusions in a region from 0.1 mm to d/8 deep from an outer surface, and have the yield ratio of the wire rod of 0.96 or higher.

LEGAL STATUS

[Date of request for examination]	22.10.2004
[Date of sending the examiner's decision of rejection]	
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]	
[Date of final disposal for application]	
[Patent number]	3854878
[Date of registration]	15.09.2006
[Number of appeal against examiner's decision of rejection]	
[Date of requesting appeal against examiner's decision of rejection]	
[Date of extinction of right]	

* NOTICES *

CLAIMS

[Claim(s)]
[Claim 1] At mass%, C:0.02 - 0.15%, Mn:0.50-2.0%, P:0.05 - 0.20%, S:0.15 - 0.50%, less than [Si:0.01%], Less than [aluminum:0.01%], N:0.002 - 0.02%, and O:0.01 - 0.03% are included. When it is the steel-wire material which consists of the remainder Fe and an unescapable impurity and by which the wire drawing was carried out after hot rolling or hot forging and the diameter of steel-wire material is set to d (mm), The low carbon sulfur system free cutting steel wire rod whose yield ratio of a wire rod the average width of face (micrometer) of the sulfide system inclusion in the field to d/8 is more than 2.8*logd from a peripheral face to a depth of 0.1mm, and is 0.96 or more.
[Claim 2] At mass%, C:0.02 - 0.15%, Mn:0.50-2.0%, P:0.05 - 0.20%, S:0.15 - 0.50%, less than [Si:0.01%], aluminum: When it is the hot rolling or the steel-wire material by which hot forging was carried out which consists of the remainder Fe and an unescapable impurity and the diameter of steel-wire material is set to D (mm) including less than [0.01%], N:0.002 - 0.02%, and O:0.01 - 0.03%, A peripheral face to a depth of 1 micrometer Low carbon sulfur system free cutting steel wire rod whose yield ratio of a wire rod the average width of face (micrometer) of the sulfide system inclusion in the field to D/8 is more than 2.8*logD, and is 0.68 or more.
[Claim 3] The low carbon sulfur system free cutting steel wire rod further indicated as a steel component to claim 1 or claim 2 containing less than [Bi:0.3%], less than [Pb:0.4%], less than [Te:0.1%], and B:0.01% or less of at least one sort.
[Claim 4] The slab which has the component indicated to claim 2 or claim 3 is heated at 1000 degrees C or more. Finish rolling temperature is hot-rolled with skin temperature as 700 degrees C or more and less than 800 degrees C. When setting [the hot-rolled steel-wire material] the diameter of steel-wire material to D (mm) for the average cooling rate V from immediately after installation to at least 500 degrees C (degree C/s) substantially during cooling by the SUTERUMO aryne at a SUTERUMO aryne, Following (1) Marginal cooling rate Vmin with which are satisfied of a formula The manufacture approach of the low carbon sulfur system free cutting steel wire rod which carries out air blast quenching above.
log Vmin =1.13(1-log D)
[Claim 5] The manufacture approach of a low carbon sulfur system free cutting steel wire rod that perform wire drawing further and a yield ratio manufactures 0.96 or more steel-wire material after obtaining the steel-wire material hot-rolled by the manufacture approach indicated by claim 4.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention relates to the low carbon sulfur system free cutting steel wire rod excellent in machinability, and its manufacture approach, when it does not contain special elements, such as Pb. In addition, with the steel-wire material indicated here, hot rolling or not only the steel-wire material that carried out hot forging but the steel-wire material which gave the wire drawing (cold drawing) after that is included.
[0002]
[Description of the Prior Art] With the components which seldom think a mechanical property as important, the low carbon sulfur system free cutting steel which added S so much is used for the screws which is manufactured so much by cutting and which are mainly a bit and piece, and nipples. The compound free cutting steel which contains Pb as a free cutting steel which has the machinability which was furthermore excellent in addition to S is also used widely. However, since Pb is harmful matter which injures health, reduction of the amount of Pb used in a free cutting steel is demanded. Although Te may also be used, since hot-working nature is checked while there is toxicity, reduction is called for.
[0003] Many examination of the machinability improvement of a low carbon sulfur system free cutting steel has so far been made. For example, the many are related with control of the number of sulfide system inclusion, size, and a gestalt as indicated by JP,1605766,B, JP,1907099,B, JP,2129869,B, JP,9-157791,A, and JP,11-293391,A. Moreover, a large number [what specified oxide system inclusion] for example, as indicated by JP,1605766,B, a JP,1907099,B (JP,4-54736,B) official report, JP,2922105,B, JP,9-71838,A, and JP,10-158781,A. On the other hand, the technique

with which ****** paid its attention to effect important for machinability at these also has few organizations and properties other than inclusion (matrix property), for example, the amount of dissolution C in a proeutectoid ferrite is specified for the stripes-like pearlite organization which followed the rolling direction in the JP,2125814,B (JP,1-11069,B) official report at JP,2740982,B.

[0004]

[Problem(s) to be Solved by the Invention] Although the technique indicated by the above-mentioned official report is important, still sufficient machinability is not obtained. For example, it sets on the technique of the indication to JP,1907099,B. the inclusion in steel — major axis of 5 micrometers the above — 2 micrometers of minor axes the above — a major axis / minor-axis ratio — five or less MnS — a total, although the content of aluminum 2O3 in oxide system inclusion is specified as an average of 15% or less with 50% or more of MnS system inclusion It makes it indispensable to contain the total quantity of Pb, Bi, and Te 0.2% or more, and sufficient machinability is not obtained without addition of these elements. This invention was made in view of this problem, and even if it is the case where special elements, such as toxic Pb, and Bi, Te, are not added, it aims at offering the low carbon sulfur system free cutting steel wire rod which has the outstanding machinability, and its suitable manufacture approach.

[0005]

[Means for Solving the Problem] Although the amount of generation and distribution condition of sulfide system inclusion affect machinability, these are mostly determined by a steel component and dissolution / casting conditions. This invention succeeds in obtaining the outstanding machinability by not controlling the amount of generation or distribution condition of sulfide system inclusion, but maintaining according to a wire size more greatly than predetermined size, without carrying out expansion of the width of face of the inclusion which influences especially machinability among the gestalten of sulfide system inclusion in a hot-rolling phase. Namely, the low carbon sulfur system free cutting steel wire rod of this invention At mass%, C:0.02 - 0.15%, Mn:0.50-2.0%, P:0.05 - 0.20%, S:0.15 - 0.50%, less than [Si:0.01%], Less than [aluminum:0.01%], N:0.002 - 0.02%, and O:0.01 - 0.03% are included. Further Or less than [Bi:0.3%], less than [Pb:0.4%], less than [Te:0.1%], When it is the steel-wire material which contains B:0.01% or less of at least one sort, and consists of the remainder Fe and an unescapable impurity and by which the wire drawing was carried out after hot rolling or hot forging and the diameter of steel-wire material is set to d (mm), From a peripheral face to a depth of 0.1mm, the average width of face

(micrometer) of the sulfide system inclusion in the field to d/8 is more than 2.8*logd, and the yield ratio of a wire rod is made or more into 0.96.

[0006] Moreover, other sulfur low carbon system free cutting steel wire rods of this invention are a peripheral face to depths of 1 micrometer, when it has said component, and it is hot rolling or the steel-wire material by which hot forging was carried out and the diameter of steel-wire material is set to D (mm). The average width of face (micrometer) of the sulfide system inclusion in the field to D/8 is more than 2.8*logD, and the yield ratio of a wire rod is made or more into 0.68.

[0007] Moreover, the manufacture approach of this invention heats the slab which has said component at 1000 degrees C or more. Finish rolling temperature is hot-rolled with skin temperature as 700 degrees C or more and less than 800 degrees C. When setting [the hot-rolled steel-wire material] the diameter of steel-wire material to D (mm) for the average cooling rate V from immediately after installation to at least 500 degrees C (degree C/s) substantially during cooling by the SUTERUMO aryne at a SUTERUMO aryne, Following (1) Marginal cooling rate Vmin with which are satisfied of a formula It is the manufacture approach of the low carbon sulfur system free cutting steel wire rod which carries out air blast quenching above. Moreover, other manufacture approaches of this invention are the manufacture approaches of a low carbon sulfur system free cutting steel wire rod that perform wire drawing further and a yield ratio manufactures 0.96 or more steel-wire material, after obtaining the steel-wire material hot-rolled by said manufacture approach.

log Vmin =1.13(1-log D)

[0008]

[Embodiment of the Invention] First, the presentation (unit mass%) of the low carbon sulfur system free cutting steel wire rod of this invention is explained.

In order that C may secure the reinforcement of steel C:0.02 to 0.15%, it adds, but while less than 0.02% of reinforcement is insufficient, toughness and ductility become superfluous and machinability also falls. On the other hand, if it exceeds 0.15%, reinforcement will become high too much and machinability will fall on the contrary. For this reason, the minimum of C is preferably made into 0.04% 0.02%, and that upper limit is preferably made into 0.12% 0.15%.

[0009] Mn: 0.50 - 2.0%Mn combines with S in steel, forms a sulfide, and raises machinability. Moreover, the red shortness by FeS generation is controlled. In order to demonstrate such effectiveness, a minimum is preferably made into 0.75% 0.50%. However, since reinforcement rises superfluously and machinability falls on the contrary even if it adds exceeding 2.0%, an upper limit is preferably made into 1.8% 2.0%.

[0010] P:0.05 - 0.20%P is effective in raising machinability, and 0.05% or more of its addition is effective. On the other hand, since effectiveness is saturated even if it adds exceeding 0.20%, let 0.20% be an upper limit.

[0011] Too little [at less than 0.15% / S / S:0.15 - 0.50%S is an element which forms a sulfide and raises machinability, and / this effectiveness] On the other hand, if it adds exceeding 0.50%, we will be anxious about the fall of hot-working nature. For this reason, a minimum is preferably made into 0.25% 0.15%, and, on the other hand, that upper limit is preferably made into 0.45% 0.50%.

[0012] less than [Si:0.01%] and aluminum: — although Si and aluminum may be used as deoxidation material 0.01% or less, if it adds exceeding both 0.01%, a hard oxide will generate and machinability will come to fall extremely. For this reason, it stops to 0.01% or less respectively.

[0013] N:0.002 - 0.02%N is effective in improving machinability, especially surface roughness. Too little [at less than 0.002% / this effectiveness] On the other hand, even if it adds exceeding 0.02%, effectiveness is not only saturated, but hot-working nature falls. For this reason, a minimum is made and an upper limit is made into 0.02% 0.002%.

[0014] O:0.01 - 0.03%O is an element which affects the size and the gestalt of MnS and raises machinability. Although for that it is required 0.01% or more, if it adds exceeding 0.03%, a hard oxide will increase and machinability will fall. For this reason, an upper limit is made into 0.03%.

[0015] although the steel-wire material of this invention is constituted by others, Remainder Fe, and an unescapable impurity — the further following range — more than a kind of Bi, Pb, and Te — or B can be added further. [component / above-mentioned]

[0016] Bi: Less than [0.3%] Bi is an element which raises machinability according to the same effectiveness as Pb. However, since effectiveness is saturated even if it adds exceeding 0.3%, it may be 0.3% or less.

[0017] Pb: Since less than [0.4%] Pb has toxicity, it is the element which should avoid use, but since there is remarkable effectiveness in machinability improvement, you may add. However, since effectiveness is saturated even if it adds exceeding 0.4%, it stops to 0.4% or less.

[0018] Te: Since 0.1%or less Te raises machinability notably according to the effectiveness which controls the expansion under hot working of MnS, you may add. However, since effectiveness is saturated even if it exceeds 0.1%, an upper limit is made into 0.1%.

[0019] B:0.01%or less B is an element which makes hot-working nature improve, and may be added. However, since hot-working nature will fall conversely if it exceeds 0.01%, it stops to 0.01% or less.

[0020] Next, the gestalt of the sulfide system inclusion of steel-wire material is explained to a detail. Although the amount of sulfide system inclusion (it is only hereafter called a sulfide.), such as MnS, and distribution are mostly decided by presentation, dissolution / casting conditions, the gestalt changes at the hot rolling after casting, and the process of hot forging. It is hard to carry out expansion at the time of rolling and forging, and has the gestalt of big width of face after processing, so that the gestalt of a sulfide is a globular form. The width of face of a sulfide has big effect on machinability also in hot rolling, the steel-wire material by which hot forging was carried out, or the wire rod which carried out wire drawing after that, and machinability improves, so that width of face is generally large. But the average width of face needed by the wire size differs. For example, when the sulfide of the same volume, the number, and a gestalt (width of face) exists in a wire rod, machinability falls, so that the one of machinability where a wire size is smaller is good and a wire size is large. If its attention is paid to a gestalt here, machinability is improvable when a wire size considers as the sulfide of sufficient width of face for it to be large.

[0021] Although there are various approaches as an element which specifies the gestalt of a sulfide, this invention prescribes average width of face. Average width of face means the average of all the sulfides within an observation visual field to the largest maximum width W by vertical width of face to this major axis L, when the maximum length of each sulfide is made into a major axis L, as shown in drawing 1 . Let average width of face be the index of a gestalt because the dependability of measurement and repeatability are the highest. On the other hand, the major axis of a sulfide and the area of inclusion have a large error by measurement, and reliable data are hard to be obtained.

[0022] When this invention person investigated the relation of the average width of face of a sulfide and the wire size (diameter) of steel-wire material which are exerted on machinability, when needed average width of face set the diameter of a wire rod to d (wire drawing material) or D (a hot rolling wire rod, hot-forging wire rod), the knowledge of being more than 2.8*log d or more than 2.8*log D was carried out so that clearly from the below-mentioned example. Machinability, especially surface roughness come to fall that the maximum width of sulfide system inclusion is less than [this].

[0023] Oxygen besides the compound mainly concerned with S represented by MnS

dissolves in a sulfide, or an oxide and the compound-ized sulfide are also contained in it. It is because these are also these effects in a machinability improvement. Although it asks for the maximum width of each sulfide by carrying out image analysis of the optical microscope observation result of one 100 times the scale factor of this, the observation location is important and observes the following fields. the part most important for machinability is shown in drawing 2 — as — from a location with a depth [a periphery front face to] of 0.1mm — ** — since it is a field to d/8 or D/8, this field is observed. On the occasion of observation, it is a field parallel to the rolling / forging direction, and measurement field area is 2 6mm. It considers as the above. Moreover, it is not necessary to etch that what is necessary is just to observe with polish. In addition, major axis of 1 micrometer The inclusion of the following is excepted and performs measurement analysis of the maximum width. This is the major axis of 1 micrometer. The inclusion of the following is because a measurement error's being large and the effect on machinability are small.

[0024] In addition, in a JP,1907099,B (JP,4-54736,B) official report, it is 2 micrometers of minor axes as one of the convention elements of a sulfide. Although specified as the above, if it is not concerned with the size of the diameter of a wire rod but is the same convention, when a wire size is large, unless it also enlarges the maximum width of a sulfide, a machinability improvement effect cannot be desired. Moreover, about the below-mentioned yield ratio which are important requirements [in / in this official report / this invention], it is unquestioned, and this invention is exception different ******.

[0025] Whenever [slab stoving temperature / in the case of hot rolling and hot forging] needs to be optimized for control of the maximum width of a sulfide, it is required for it to consider as at least 1000 degrees C or more, and it is good to make it preferably 1040 degrees C or more. At less than 1000 degrees C, expansion of a sulfide is controlled in subsequent rolling and forging, and it becomes difficult to enlarge average width of face of a sulfide. Whenever [stoving temperature / of slab] is measured in the phase to which the billet came out of the heating furnace. control of whenever [said slab stoving temperature] — in addition, performing policies, such as lessening powerful deoxidation elements, such as making late the cooling rate at the time of coagulation, making [many] the amount of oxygen in molten steel, aluminum, and Si, to coincidence can also expect more the increase-ized effectiveness of the average width of face of a sulfide. But if there are too many amounts of oxygen in molten steel, since it will come to generate the hard oxide which has a bad influence on machinability, cautions are required.

[0026] For the improvement of machinability, the knowledge of it being important carrying out not only the average width of face of a sulfide but the yield ratio (yield strength/tensile strength) YR beyond a specific value was carried out. That is, in the steel-wire material by which the wire drawing was carried out, it is required to make YR or more into 0.96. Less than by 0.96, not only surface roughness but a dimensional change becomes large in machinability, and the tool life specified by the dimensional change falls. Desirably, it is good to carry out to 0.97 or more. By making a yield ratio high, shearing of scraps is stabilized and it comes to happen at the same time the energy of a shear strain in the shear region which generates scraps falls. Consequently, cutting force decreases, tool wear decreases and a dimensional change also becomes good. In addition to the above, surface roughness improves with stabilization of cutting. In addition, YR in a low carbon sulfur free cutting steel (SAE, AISI specification) equivalent to this invention is usually 0.77 to about 0.84 (55 75 8 JSSC, VOL. NO. 1972p table 3-1).

[0027] On the other hand, YR is made or more into 0.68 in the wire rod after the hot rolling before a wire drawing, and hot forging. Desirably, it is good to carry out to 0.70 or more. It is necessary to carry out 0.68 or more for satisfying the machinability in the case of being cut after rolling / forging. Moreover, if this property is not satisfied when carrying out a wire drawing after hot working, on the usual cold drawing conditions, it will become difficult to make YR of the wire rod after a wire drawing or more into 0.96. Since there is an inclination for a yield ratio to become low, in steel with low tensile strength, in order to attain the above-mentioned YR value, it is desirable to be referred to as 440 or more MPas in the viewpoint of tensile strength. In addition, YR of the steel materials of the hot rolling as in a low carbon sulfur free cutting steel (SAE, AISI specification) equivalent to this invention is usually 0.50 to about 0.60 (Table 3-1 of said reference).

[0028] In order to control the yield ratio of the wire rod by hot rolling, control of the cooling rate after a finish rolled bar affair and rolling is important. In addition, also in hot forging, control of the cooling rate after finish forging conditions and forging is important, but since these conditions are the same as that of the case of hot rolling, the case of hot rolling is hereafter explained to a detail.

[0029] By this invention, skin temperature performs finish rolling temperature at 700 degrees C or more and less than 800 degrees C. At less than 700 degrees C, it becomes rolling in a two-phase region, the organization after rolling becomes an ununiformity, and mechanical properties, such as a yield ratio, come to deteriorate as a result. On the other hand, in rolling of 800 degrees C or more, a detailed organization

is not obtained but a predetermined yield ratio ceases to be obtained. In order to obtain 0.96 or more constantly with the wire rod by 0.68 or more and the wire drawing like this invention with the wire rod according a yield ratio to hot rolling and hot forging, it is indispensable to make an organization detailed further as compared with level conventionally, and, for that purpose, it is required to perform finish rolling temperature in the front face of steel materials at 700 degrees C or more and less than 800 degrees C, as described above. If it is these conditions, it can be made 440 or more MPas also about the tensile strength of hot rolling material and hot-forging material. Although finish rolling temperature and whenever [slab stoving temperature] interlocked conventionally in many cases, in order to obtain the average width of face and the yield ratio of a sulfide concerning this invention, it is required to control both independently. That is, although the high thing of whenever [slab stoving temperature] is desirable in order to enlarge average width of face of sulfide system inclusion, it is necessary to make finish rolling temperature low.

[0030] In addition, conventionally, finish rolling temperature has 800-1000 degrees C or common 800-900 degrees C, and finish rolling temperature is too high [temperature] as compared with this invention as indicated by JP,1-224103,A, JP,5-247585,A, and JP,5-331592,A. Finish rolling temperature is reduced rather than whenever [stoving temperature / of slab], by rolling out in 800-1000 degrees C, the microscopic organization after rolling is made into homogeneity with a fine grain, and the need for raising a yield ratio is indicated by JP,1-224103,A. However, it is clear that the yield ratio which an actual yield ratio or tensile strength are not indicated, but starts this invention is not obtained.

[0031] In case the steel-wire material hot-rolled in this invention is cooled by the SUTERUMO aryne about the cooling rate after hot rolling, when setting the diameter of steel-wire material to D (mm) for the average cooling rate V to at least 500 degrees C from from (degree C/s) immediately after laying in a SUTERUMO aryne substantially, it is following (1). Marginal cooling rate Vmin with which are satisfied of a formula Air blast quenching is carried out above. Installation in the first part which has an air-blast-quenching facility, saying "lay at the time of parenchyma" is meant. Although the cooling rate of the wire rod in the case of being cooled by SUTERUMOA conveyor changes with the non-dense sections and the dense parts of a wire rod coil strictly, it means the cooling rate of an average of these cooling rates.

log Vmin =1.13 (1-log D) .... (1) [0032] In cooling by the SUTERUMO aryne, all as for which the average cooling rate to 500 degrees C matters is because are hard coming to generate a phase transformation and grain growth, and the effect on machinability

becomes small, so the effect of a cooling rate can be disregarded at less than 500 degrees C. As for this invention person, said cooling rate affects the organization of a hot rolling wire rod under said finish rolling temperature. The result of having thought that machinability would be affected if lengthened, and having given various cooling conditions, and having gazed at the organization, Marginal cooling rate Vmin with which it is [the average cooling rate V to 500 degrees C (degree C/s)] satisfied of the above-mentioned (1) formula The knowledge of a yield ratio being securable 0.96 or more with a hot rolling wire rod by 0.68 or more and the wire drawing material which carried out the wire drawing further was carried out by carrying out air blast quenching above. This is for a yield ratio to go up by being able to make the organization of rolled stock homogeneity detailed and obtaining such a homogeneity detailed organization by speeding up a cooling rate as mentioned above.

[0033] In addition, there are few hot rolling exerted on the machinability of a low carbon sulfur system free cutting steel wire rod and examples in which the effect of the cooling process after hot forging was considered. The example which covers and anneals a wire rod on furnace cooling or a SUTERUMO aryne as the cooling approach although it supposes that control of a stripes-like pearlite is important for a JP,2125814,B (JP,7-11069,B) official report, it is indicated that the later one of the cooling rate after rolling / forging is desirable and the cooling rate is not shown quantitatively is shown, and it can observe that it is remarkable annealing. For example, it also sets to a sample with a diameter of 18mm which is one of the examples, and is the above (1). It is expected that it is 0.4 degrees C/s or less later than the threshold value of 0.51 degrees C/s by the formula in late cooling rate. Moreover, after annealing even 500-700 degrees C and depositing a proeutectoid ferrite, raising machinability by quenching and making Dissolution C remain in a proeutectoid ferrite is shown in JP,2740982,B. However, it only says that after reheating heat treatment to austenitize from a room temperature, or it may be after hot working, and like this invention, a ultimate-pressure total, temperature (finish rolling temperature) is not made into requirements, and is not indicated and suggested.

[0034] The cold drawing working ratio after hot rolling besides the finish rolling temperature in the above-mentioned hot rolling and a cooling rate also influences control of the yield ratio of wire drawing material. The rate of wire drawing is usually about 5 - 30%. There are problems, like if it separates from this range, reservation of perfect circle nature or linearity will become difficult, and a mechanical failure becomes excessive, and large modification is difficult. For this reason, it is the phase of obtaining the hot rolling wire rod used as the material of wire drawing material, and

it is required to secure said yield ratio 0.68. 0.96 or more ******** are [with this] securable with said usual rate of wire drawing.

[0035]

[Example] the steel of the various presentations (mass%) shown in the [example 1] table 1 is ingoted at a system furnace, and it is shown in Table 2 after that — after many things were substantially laid in the rolled bar affair and the SUTERUMO aryne, the hot rolling wire rod was manufactured with the average cooling rate (only henceforth an average cooling rate) to 500 degrees C. Then, except for some wire rods, wire drawing was performed further. The rate of wire drawing in this case and the last wire size were also shown in this table.

[0036] To the obtained wire rod, the average width of face of a sulfide was described previously, and it measured in the way. Moreover, the mechanical property was measured by the tension test (JISZ2241). Moreover, the machinability trial was performed in the following way. As shown in drawing 3 , the wire rod W was fixed to the automatic lathe free [the rotation to the circumference of that axial center], and after it sent in perpendicularly the high-speed-steel tool (SKH4) B and it carried out foaming to this wire rod W, the machined surface granularity after cutting was measured. Moreover, the dimensional change after 3000-piece cutting was measured. Moreover, about the wire rod of a hot rolling as, after removing the scale by cutting or pin center,large loess grinding, the machinability trial was carried out. The conditions of foaming were made into cutting speed 92 m/min, tool feed-rate 0.03 mm/rev, and 1.0mm of slitting.

[0037] These measurement results are shown in Table 3. It sets to this table and is 42 micrometers of machined surface granularity. The following, 20 micrometers of dimensional changes The following was made into the index that machinability is superior, and the sample with which are satisfied of this was made into the example of invention. Moreover, they are log d (d: diameter mm of wire drawing material) or log D (D: diameter mm of a hot rolling wire rod), and sulfide average width-of-face mum about the sample with which were satisfied of the conditions of the yield ratio of this invention. The classified graph with the example of invention and the example of a comparison is shown for relation in drawing 4 . The broken line in drawing 4 is a straight line of average width-of-face (micrometer) =2.8*log d(D).

[0038] Table 3 and drawing 4 show that surface roughness and the dimensional change of the average width of face of a sulfide are good, and it moreover excels [thing / more than 2.8logd(s) (D)] in machinability by the yield ratio of the wire rod after a wire drawing having attained [the yield ratio of rolled stock] 0.96 or more by

0.68 or more samples. Since there are much Si and aluminum which are a strong deoxidation element and there are few amounts of oxygen, a suitable sulfide is not obtained but the average width of face of the steel type D of sample No.12 is also smaller than criteria. For this reason, machinability is also falling.

[0039]

[Table 1]

[0040]

[Table 2]

[0041]
[Table 3]

[0042] The steel type A of a publication was used for the [example 2] table 1, 1000-1025 degrees C cost whenever [billet stoving temperature], and it considered as the finish rolling temperature of 750-800 degrees C, after rolling, the average cooling rate in a SUTERUMO aryne was variously changed, as shown in Table 4, and the hot rolling wire rod of 9.5mm of wire sizes was obtained. Then, it carried out the wire drawing, having used the rate of wire drawing as 29%, and the wire drawing material of 8.0mm of wire sizes was obtained.

[0043] the place which measured the average width of face of a sulfide like the example 1 about the obtained wire rod -- 2.7-3.1 micrometers it is -- it was a larger value than log d(d= 8.0) =0.90. Moreover, a mechanical property and machinability were investigated. These results are collectively shown in Table 4. The marginal

cooling rate called for by log Vmin =1.13 (1-log D) is 1.06 degrees C/s.

[0044] From Table 4, it was checked by cooling the average cooling rate on the SUTERUMO aryne after hot rolling above a marginal cooling rate that a predetermined yield ratio is obtained and good machinability is obtained.

[0045]

[Table 4]

[0046]

[Effect of the Invention] Since the low carbon sulfur free cutting steel wire rod of this invention is carried out to more than 2.8*log d (D) under a predetermined component and a predetermined yield ratio when making average width of face of sulfide system inclusion into the diameters d (wire drawing material) and D (a hot rolling wire rod, hot-forging wire rod) of a wire rod, even if it is the case where special elements, such as Pb, are not used, it can obtain good machinability. Moreover, according to the manufacture approach of this invention, the steel-wire material concerning this invention can be manufactured easily industrially, and it excels in productivity.

[Translation done.]

* NOTICES *

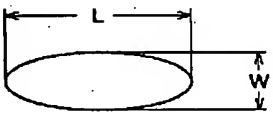
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the measurement point explanatory view of the dimension which specifies the gestalt of a sulfide.
[Drawing 2] It is the cross-sectional view of the wire rod in which the observation field of a sulfide is shown.
[Drawing 3] It is the cutting point explanatory view of the machinability trial in an example.
[Drawing 4] It is the graph which indicates the relation between the example of invention, and the example of a comparison (superiority or inferiority of machinability) to be the average width of face of the sulfide in an example, and 2.8*log d (D).

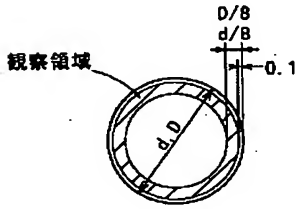
[Translation done.]

Drawing selection drawing 1



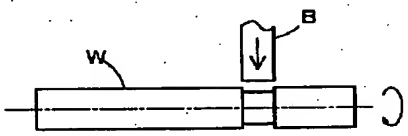
[Translation done.]

Drawing selection drawing 2



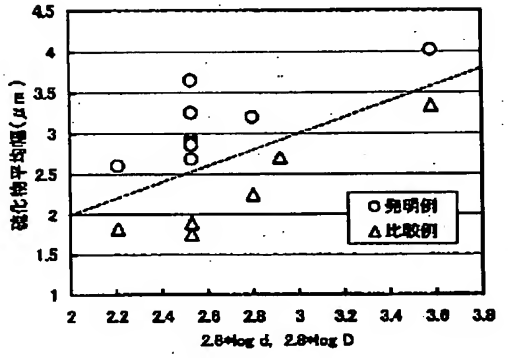
[Translation done.]

Drawing selection drawing 3



[Translation done.]

Drawing selection drawing 4



[Translation done.]